PRICE $5.00

Model ABC 18–0.5(M)

Serial No. E-23900

INSTRUCTION MANUAL

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ABC

REGULATED DC SUPPLY

TRANSISTORIZED

design group

Model ABC 18–0.5(M)

Serial No. E-23900

INSTRUCTION MANUAL

The KEPCO equipment described in this instruction manual is of proprietary design, covered by one or more of the following United States patents, or by patents pending:

2,992,379	3,210,619
2,992,386	3,226,628
3,028,538	3,241,054
3,056,905	3,241,042
3,088,053	3,243,690
3,092,757	3,243,749
3,112,439	3,275,925
3,128,423	3,275,927
3,131,344	3,275,948

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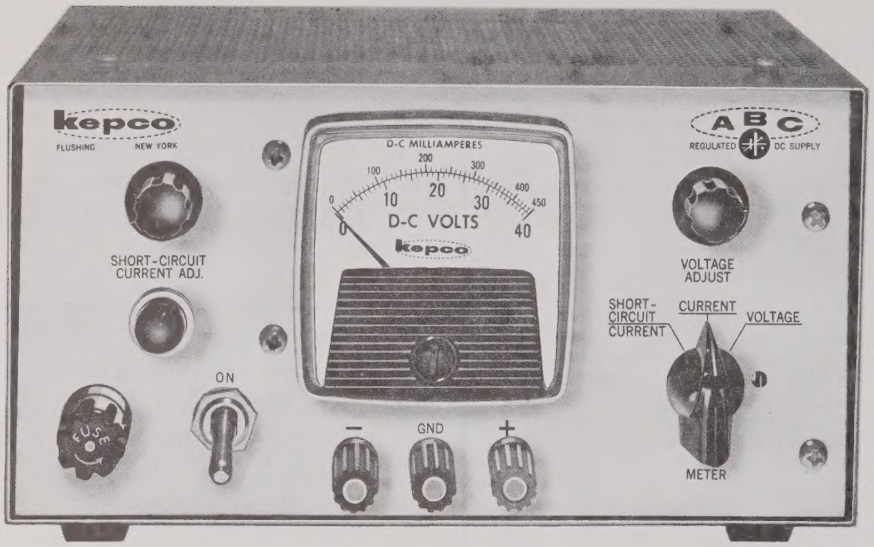


FIG. 1-1: ABC POWER SUPPLY, TYPICAL FRONT VIEW.

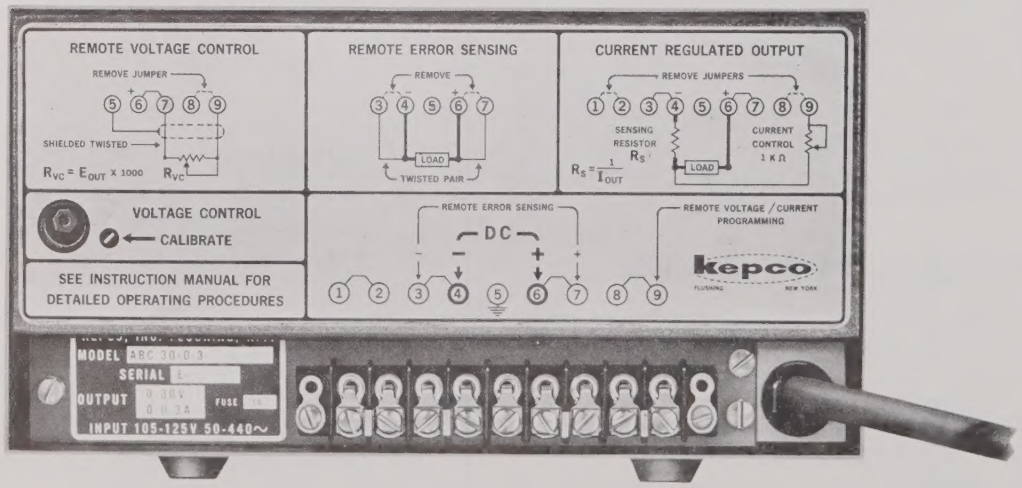


FIG. 1-2: ABC POWER SUPPLY, TYPICAL REAR VIEW.

SECTION 1 INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This manual contains instructions for the installation, operation and maintenance of the KEPCO Series ABC All-Transistor Power Supplies.

1-3 GENERAL DESCRIPTION

1-4 The Kepco Series ABC power supply is a portable, precision, 0.05% regulated DC power supply, with continuously variable output voltage, and adjustable output current limiting. The models in this series employ power transistors as series pass elements, and solid-state reference and amplifier circuits in a feedback controlled, closed-loop series regulating system. They have provisions for remote error sensing, and are fully programmable for automatic or remote operation. Each model is equipped with a dual function voltmeter/ammeter as standard equipment, or is available optionally without meter. For the unmetered version of the ABC power supply, the suffix "M" is deleted from the model number. All models in the ABC series are identical except for the differences listed in Table 1-1.

MODEL	DC OUTPUT RANGE		OUTPUT IMPEDANCE OHMS MAX.		
	VOLTS	AMPS	DC to 100 CPS	100 CPS to 1 KC	1 KC to 100 KC + μH
ABC 2–1M	0–2	0–1	0.001	0.01	0.1 + 0.5
ABC 7.5–2M	0–7.5	0–2	0.002	0.01	0.05+ 0.5
ABC 10–0.75M	0–10	0–0.75	0.007	0.02	0.1 + 1
ABC 15–1M	0–15	0–1	0.008	0.01	0.05+ 0.5
ABC 18–0.5M	0–18	0–0.5	0.02	0.02	0.1 + 1
ABC 30–0.3M	0–30	0–0.3	0.05	0.02	0.1 + 1
ABC 40–0.5M	0–40	0–0.5	0.04	0.02	0.05+ 0.5
ABC 100–0.2M	0–100	0–0.2	0.25	0.05	0.05+ 1

TABLE 1-1: OUTPUT RANGE AND IMPEDANCE, ABC POWER SUPPLIES

1-5 ACCESSORIES (OPTIONAL, NOT SUPPLIED)

1-6 The ABC power supplies can be operated without any additional, external components.

1-7 **Electrical Accessories.** Several electrical accessories, extending the useful operation of the ABC power supplies are available from KEPCO and are described in detail in the Kepco Catalog which is available from your KEPCO Field-Engineering Office or directly from KEPCO, FLUSHING, NEW YORK, 11352. Among these accessories are precision programming devices and over/under voltage protectors.

1-8 **Mechanical Accessories.** Dual and single rack-adaptors facilitate the mounting of the ABC power supplies into standard racks.

a) Single Mounting, KEPCO Model RA 5
b) Dual Mounting, KEPCO Model RA 4

1-9 **SPECIFICATIONS, GENERAL.** (See Also Table 1-1)

a) **Input Requirements:** 105-125 or 210-250V AC, 50-400 Hz single phase.
b) **Ambient Operating Temperature:** –20°C to +50°C maximum.
c) **Storage Temperature:** –40°C to +85°C maximum.
d) **Isolation Voltage:** A maximum of 500 volts can be connected between the chassis and either output terminal.

1-10 SPECIFICATIONS, VOLTAGE REGULATION MODE

a) **Regulation:**
   1) *Line:* Less than 0.05% or 1 mV, whichever is greater, output voltage change for 105-125V AC or 210-250V AC line variation, at any output voltage within the specified range.
   2) *Load:* Less than 0.05% or 1 mV, output voltage change, whichever is greater, for no load to full load change at any output voltage within the specified range.

b) **Stability:** Output voltage varies less than 0.05% or 3 mV, whichever is greater, over a period of 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.

c) **Temperature Coefficient:** Output voltage changes less than 0.05% per °C.

d) **Ripple:** Less than 0.25 mV rms.

e) **Recovery Time:** 50 microseconds.

f) **Output Impedance:** Specified for each model within the load frequency range shown in Table 1-1. Above 10 kHz include the reactive impedance of the effective series inductance as indicated.

1-11 SPECIFICATIONS, CURRENT REGULATION MODE (EXTERNAL SENSING)

a) **Output Range:** Current regulation from 1 mA to 100% of the maximum rated current.

b) **Compliance:** Voltage compliance range is zero to 100% of the maximum output voltage.

For any selected current value, the output voltage is automatically varied throughout the compliance range as required to regulate the output current through a variable load.

c) **Regulation:**
   1) *Line:* For 105-125V AC, or 210-250V AC line variations, output current changes less than 0.1% when the specified voltage sample is maintained across the external sensing resistor.
   2) *Load:* For the maximum change in load resistance, within the rated compliance range, output current changes less than 0.5% when the specified voltage sample is maintained across the external sensing resistor.
   3) The sensing resistor is chosen to produce a one volt drop at the maximum operating current. A separate control is used externally to provide high resolution current adjustability.

d) **Stability:** Output current varies less than 0.1% or 1 mA, whichever is greater, over a period of 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.

e) **Temperature Coefficient:** Output current changes less than 0.01% per °C.

f) **Ripple:** Less than 0.1% of maximum current, rms.

1-12 SPECIFICATIONS, PERFORMANCE

a) **Controls:** Continuously adjustable 10-turn voltage control permits output settings from zero to maximum voltage. Resolution: 0.05% of maximum output.

b) **Programming:** Special terminals provide for remote resistive programming of voltage or current at 1000 ohms per volt. Programming terminals are also provided for programming by means of remotely located voltage or current signals.

c) **Current Limit Control:** A single turn control provides adjustable current limiting from 25% to 150% of rated full-load current.

d) **Short-Circuit Protection:** Unique current limiting circuitry permits continuous operation into a short-circuit without the aid of fuses, circuit breakers or relays. Output returns instantly to the operating voltage when the overload is removed.

e) **Remote Error Sensing:** Error sensing terminals enable specified voltage regulation to be maintained directly at the load by compensating for voltage drops up to 0.5 volts across each load supply lead.

f) **Series/Parallel Operation:** Series connection of identical units is possible up to the specified isolation voltage limit, and provided the necessary precautions are taken. (See Par. 3-25.) ABC supplies can be parallel connected and will share the load by means of their current limiting feature. (See Par. 3-28.)

g) **Cooling;** Heat removal is by natural convection, without blowers.

h) **Overshoot:** No output voltage overshoot from turn-on, turn-off, or power failure for output settings above 25% of maximum rated output voltage. Below 25%, output voltage overshoot is a function of load current and is negligible for loads in excess of 10% of the maximum rated load current.

1-13 SPECIFICATIONS, PHYSICAL (Refer to Fig. 1-3)

a) **Meters:** Model numbers in Table 1-1 include 2½" combination voltmeter, ammeter; 2% full scale accuracy. Unmetered Models have the suffix "M" deleted from their model number, e.g. ABC 40-0.5 for unit without meters.

b) **Terminations** (See Also Par. 2-3)

1) *Front Panel:* DC output and ground (5-way) terminals. 10-turn voltage control, short-circuit current adjusting control, AC on-off switch, pilot light and fuse. Volt/amp meter and meter selector switch provided on metered units only.

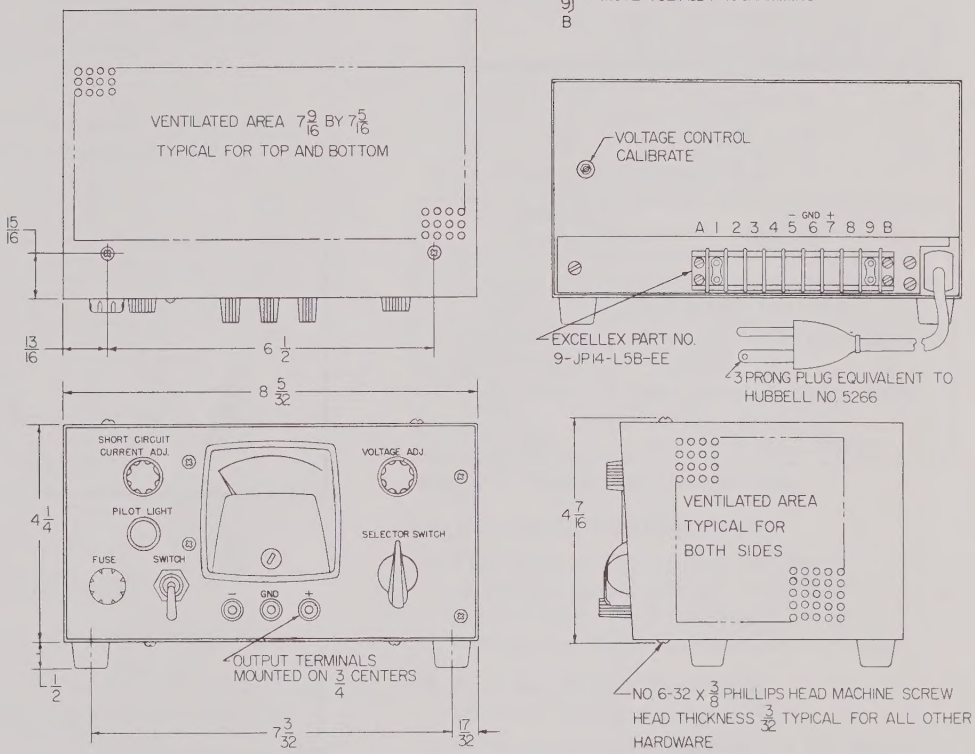
2) *Rear of Chassis:* Barrier strip terminations are provided for DC output and ground connections, resistive or voltage programming, current regulator connections, and remote error sensing. Access is provided for the voltage calibration control. Output terminals are isolated from the chassis, either positive or negative terminals may be grounded.

c) **Dimensions:** 4¼" H × 8$\frac{5}{32}$" W. See outline drawing (Fig. 1-3) for depth dimensions of each model.

d) **Standard Finish:** Panel, etched aluminum– brushed and coated. Case, gray hammertone. (Special finishes to order.)

REAR OUTPUT TERMINAL FUNCTIONS

A
1, 2 INTERNAL LOAD
3- MINUS REMOTE ERROR SENSING
4- MINUS OUTPUT
5- GROUND
6- PLUS OUTPUT
7- PLUS REMOTE ERROR SENSING
8, 9 REMOTE VOLTAGE PROGRAMMING
B



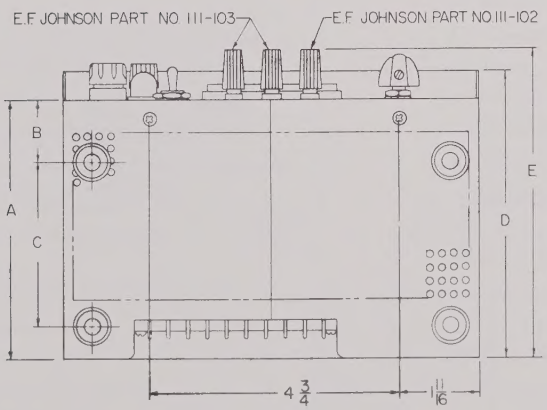


FIG. 1-3: OUTLINE DRAWINGS KEPCO ABC POWER SUPPLIES. ALL-TRANSISTOR GROUP

NOTES:

1) MATERIAL,
A) COVER: No. 16 COLD ROLLED STEEL, GRAY HAMMERTONE FINISH.
B) PANEL: 14 GAGE (0.063) ALUM. ALLOY No. 5052-H32. BRUSHED FINISH.

2) DIMENSIONS:

MODEL	A	B	C	D	E
ABC 2-1	5 1/8	1 1/4	3 3/8	5 5/8	6
ABC 7.5-2	9 1/8	1 3/8	6 3/8	9 5/8	10 1/16
ABC 10-0.75	5 1/8	1 1/4	3 3/8	5 5/8	6
ABC 15-1	9 1/8	1 3/8	6 3/8	9 5/8	10 1/16
ABC 18-0.5	5 1/8	1 1/4	3 3/8	5 5/8	6
ABC 30-0.3	5 1/8	1 1/4	3 3/8	5 5/8	6
ABC 40-0.5	9 1/8	1 3/8	6 3/8	9 5/8	10 1/16
ABC 100-0.2	9 1/8	1 3/8	6 3/8	9 5/8	10 1/16

3) FUSE DATA: ALL MODELS 1A SL.B.

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SECTION 2 INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This power supply has been inspected and tested at the factory prior to packing and is shipped ready for operation. After careful unpacking, inspect the instrument for shipping damage before attempting to operate it. Perform the operational check as described in Paragraph 2-13 below. If there is evidence of shipping damage, file a claim immediately with the responsible transport service.

2-3 TERMINATIONS

a) **Front Panel:** Refer to Fig. 2-1 and Table 2-1.

b) **Rear:** Refer to Fig. 2-2 and Table 2-2.

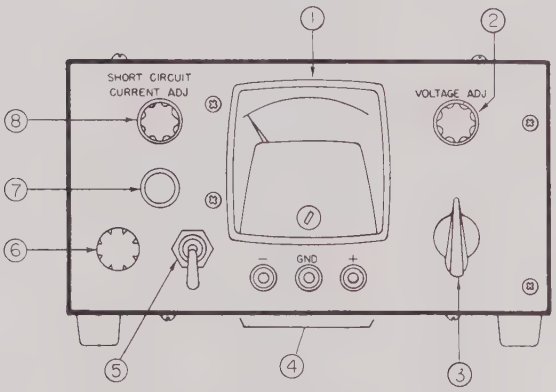


FIG. 2-1: TERMINALS AND CONTROLS, FRONT.

NO.	TERMINAL OR CONTROL	FUNCTION
1*	Meter	Measures output voltage or output current or short-circuit current.
2	Voltage Control	Ten-Turn Potentiometer Sets output voltage.
3*	Meter Function Switch	Selects voltage/current measured by meter.
4	Output Terminals	Load connection, and ground terminal.
5	On-Off Switch	Turns line power "on" or "off".
6	Fuse	Line fuse, accessible on front panel.
7	Pilot Light	Indicates line power "on" or "off".
8	Short Circuit Current Adjust	Adjusts Magnitude of short circuit current (continuously adjustable).

TABLE 2-1: TERMINALS AND CONTROLS, FRONT. *Metered units only

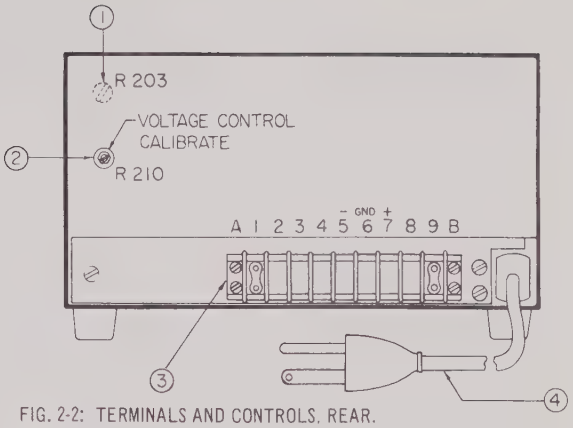


FIG. 2-2: TERMINALS AND CONTROLS, REAR.

NO.	TERMINAL OR CONTROL	FUNCTION
1	Current Limit Adjust	Adjusts upper-limit of Short-Circuit Current. (Accessible After case removal).
2	Voltage Control Calibration	Adjusts maximum output voltage (I_b Adjust). (Calibrate Control)
3	Rear Barrier Strip	Output, Programming, and Error Sensing Terminals.
4	Line Cord	Connects Supply To A.C. Powerline.

TABLE 2-2: TERMINALS AND CONTROLS, REAR.

2-4 A.C. POWER REQUIREMENTS

2-5 This power supply is normally shipped for operation on a single phase, 115V AC line. If 230V AC operation is desired, the transformer primary link connections must be changed as described below.

2-6 Procedure for 230V Conversion
(Refer to Fig. 2-3 and Fig. 2-5)

a) Disconnect unit from power line and remove from case by removing the five (5) holding screws and sliding the case back until the transformer terminals are visible. (Refer to Fig. 2-4.)

b) Remove jumpers between terminals 1-2 and 3-4.

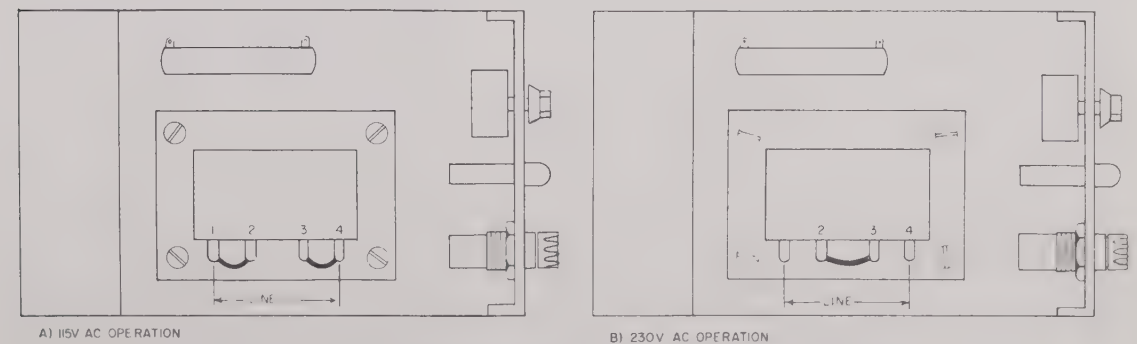
c) Place wire jumper between terminals 2 and 3 as shown and solder in place.

d) Replace 1A fuse by 0.5A, "Slow Blow" type.

e) Replace case and secure with holding screws.

2-7 GROUNDING

2-8 For safety reasons, it is imperative that the metal chassis of the power supply is always kept at ground



A) 115V AC OPERATION B) 230V AC OPERATION

FIG. 2-3: TRANSFORMER PRIMARY CONNECTIONS FOR 5⅜" DEEP ABC POWER SUPPLIES.

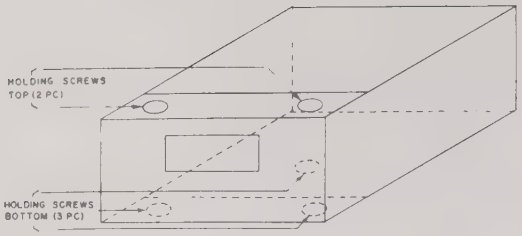


FIG. 2-4: CASE REMOVAL. ABC POWER SUPPLY.

potential. If the safety line cord and three prong plug are used in connection with a properly grounded outlet, this is taken care of automatically. However, if an adaptor is used for a non-grounded outlet, the chassis must be grounded separately.

2-9 ISOLATION

2-10 The D.C. output terminals of the ABC power supply are isolated from the chassis and from the power line, except for a capacitive connection from the positive output to chassis. Either side of the supply may be grounded, or a maximum of 500V DC (plus the supply voltage) can be connected between chassis or either output terminal.

2-11 COOLING

2-12 This power supply is designed to have sufficient convection cooling through its perforated, wrap-around case. Allow sufficient space around the unit to allow free air circulation. If the instrument must be mounted into confined space, forced air cooling may be necessary to keep the surrounding temperature within the ambient temperature rating of the ABC power supply.

2-13 OPERATIONAL CHECK

2-14 **Before Turn-on.** Check all terminal screws at the rear barrier strip. All jumper links and terminal screws must be tight for proper functioning of the power supply.

2-15 **Turn-on** (Refer to Fig. 2-1)

a) Rotate "Voltage Control" clockwise, approximately two turns from its maximum counterclockwise position.

b) Connect power supply to the line and turn power switch "on".

c) Turn "Short Circuit Current Adjust" to its maximum clockwise position.

d) Turn "Voltage Control" slowly clockwise and then counterclockwise. With the "Meter" switch in the "Voltage" position, observe panel meter

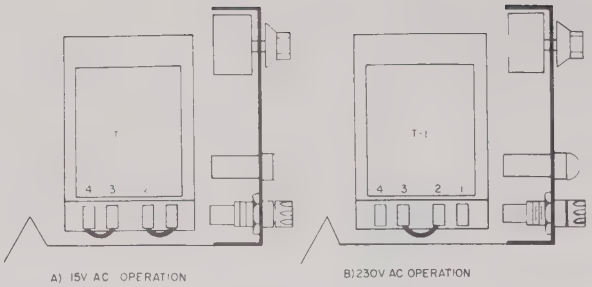


FIG. 2-5: TRANSFORMER PRIMARY CONNECTIONS FOR 9⅝" DEEP ABC POWER SUPPLIES.

for a smooth increase or decrease of the output voltage. When the "Voltage Control" is turned fully clockwise, the output voltage should equal or slightly exceed the maximum voltage rating of the power supply. When the control is fully counterclockwise, the output voltage should be zero or slightly negative.

2-16 **D.C. OUTPUT CONNECTIONS:** The load may be connected at the binding post terminals at the front of the unit, or at rear terminals, (4) and (6). *Specified regulation applies to the rear terminals only and is measured across the error sensing terminals (3) and (7).*

2-17 OVERLOAD PROTECTION

2-18 The "Short Circuit Current Adjust" control on the front panel may be adjusted over a range from approximately 25% to 150% of the rated maximum output current of the power supply. The control should be set to at least 150% of the load current at which the supply is to be operated. To facilitate this setting, the ABC power supply is equipped with a meter function switch (Fig. 2-1), which applies (in its maximum counterclockwise position) a short circuit across the supply. The short circuit current resulting may be read directly on the panel meter or, on unmetered units, on an external ampere meter across the output terminals. Simultaneously, the "Short Circuit Current Adjust" on the front panel must be adjusted to the desired load current, plus 50%. If, for example, 80 ma of load current are required, the short circuit current must be adjusted to at least 120 ma.

2-19 If lower settings of current limits are not specifically required, it is recommended that the "Short Circuit Current Adjust" control be set to its maximum clockwise position. At this setting, the output can be operated at any current up to its rated maximum. Overload protection will still be given at 150% of the rated maximum output current.

SECTION 3 SPECIAL OPERATING PROCEDURES

3-1 INTRODUCTION TO PROGRAMMING

3-2 The purpose of this paragraph is to introduce the user of this equipment to the terminology and the basic relationships pertaining to the operation of the ABC power supply. These relationships become especially significant in programming and are listed below:

3-3 (Refer to Fig. 3-1) The basic equations governing the operation of the KEPCO Bridge at balance ($V_{AA_1} = 0$) are:

a)
$$\frac{E_o}{E_r} = \frac{R_{vc}}{R_r} \qquad \text{(Eq. 1)}$$

$$\frac{E_r}{R_r} = I_b \qquad \text{(Eq. 2)}$$

$$E_o = I_b R_{vc} \qquad \text{(Eq. 3)}$$

Where E_o = Output Voltage
E_r = Reference Voltage
R_r = Reference Resistor
R_{vc} = Control Resistance
I_b = Bridge Current

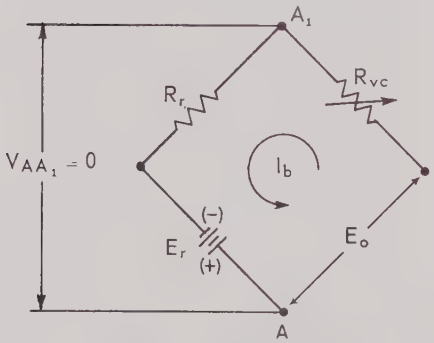


FIG. 3-1: KEPCO COMPARISON BRIDGE, SIMPLIFIED.

b) The ratio of the number of ohms of control resistance needed to change the output by one volt, is termed the "Control Ratio". As seen from equation (1), the "Control Ratio" depends on the bridge current, I_b:

$$\frac{E_o}{R_{vc}} = I_b .$$

I_b is a nominal 1 mA in the ABC supplies, and can be precisely adjusted as outlined in Paragraph 3-5. Consequently, for each volt of output voltage E_o, 1000 ohms of Control Resistance (R_{vc}) must be provided.

c) Rewriting equation (1),

$$E_o = E_r \frac{R_{vc}}{R_r} ,$$

we can make E_r the variable which controls E_o. This type of control is referred to as "Voltage Programming" and is covered in Paragraph 3-20.

d) Many other modes of control are of course possible, some of which are described in the following paragraphs. For a more extensive treatment and a more detailed theoretical view of power supply applications, see the Kepco "Power Supply Handbook" available from your Kepco Representative or directly from Kepco Applications Engineering Department.

3-4 RESISTANCE PROGRAMMING

3-5 Adjustments for Exact Programming Ratio

A precise programming ratio is imperative for programming with precision decades or other highly accurate resistances. It can be achieved conveniently on the ABC power supplies by:

a) Adjusting the bridge current I_b. Two methods will be described below, one by directly measuring I_b, and the other by accurately monitoring the output voltage E_o.

b) Adjusting the offset voltage. Again referring to equation (3), $E_o = I_b R_{vc}$, we see that if R_{vc} (the control resistance) is zero (shorted), E_o should be zero. However, a small, negative offset voltage will be encountered at the output under this condition and can be compensated for as shown below.

3-6 Both "inaccuracies", the nominal bridge-current, as well as the slight negative offset voltage, have been purposely designed into the circuit to facilitate precision adjustment.

3-7 Procedure I (Accuracy of Programming Ratio adjustment will depend on the accuracy of the ammeter and the programming resistors)

a) *Equipment Required:*

1) D.C. ammeter, accuracy ½% or better, range 1.5 mA (M2).
2) Programming resistors (Precision Decade).
3) Potentiometer, approx. 200 ohm W.W., 1 W.
4) D.C. voltmeter, 3 volts full scale (M1).
5) Switch, SPST.

b) Connect calibration set-up as shown in Fig. 3-2 and set precision decade to 1 KΩ.

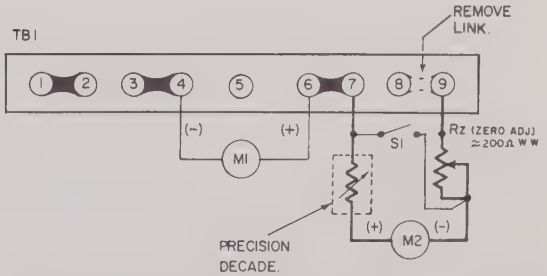


FIG. 3-2: ADJUSTMENT FOR EXACT PROGRAMMING RATIO, METHOD 1

c) Observe exact position of the zero point on the scale of M-1.

d) Connect power supply to AC line. With S-1 open, turn supply "on". Approximately 1 volt will be read on M-1 (this reading is irrelevant to the adjustment).

e) Adjust R210 ("Voltage Control Calibration") so that M-2 indicates exactly 1 mA. (Refer to Fig. 2-2 for location of R210.)

f) Close S-1 and adjust R_z, so that M-1 reads precisely zero volts and its indicator coincides with the previously observed zero point on M-1.

g) Open S-1 and repeat (e) and (f) until no further interaction of the two adjustments can be observed.

3-8 **Procedure II** (Accuracy of Programming Ratio adjustment will depend on voltmeter and programming resistors)

a) *Equipment Required:*

1) D.C. differential or digital voltmeter.
2) Programming resistors (Precision Decade).
3) Potentiometer, approx. 200 ohm, W.W., 1 W.
4) Switch, SPST.

b) Connect calibration set-up as shown in Fig. 3-3 and set precision decade to 1 KΩ.

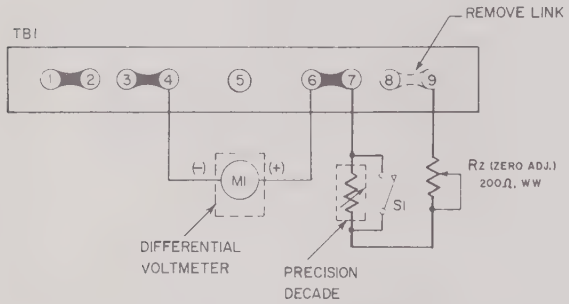


FIG. 3-3: ADJUSTMENT FOR EXACT PROGRAMMING RATIO, METHOD 2

c) Connect power supply to AC line. With S-1 open, turn supply "on".

d) Adjust R210 ("Voltage Control Calibration") so that 1 volt is read out on M-1. (Refer to Fig. 2-2 for location of R210.)

e) Close S-1 and adjust R_z to exactly zero on M-1.

f) Repeat (d) and (e) until no further interaction of the two adjustments is observed.

g) Remove M-1 and S-1. The exact programming ratio is now established. Resistance programming with a linearity of better than 0.05% may be achieved if the precision decade has accuracy of 0.01% or better.

3-9 REMOTE ERROR SENSING

3-10 Error sensing terminals (3) and (7) on the rear barrier-strip are the input to the supplies' regulating amplifier and are normally connected to the output terminals (4) and (6) by means of removable jumper-links. Specified performance will be provided at these points, with links in place. Since voltage drops across the load wires would degrade regulation at the load, the links connecting the sensing terminals to the output terminals can be removed and the sensing terminals can be connected directly at the load, thus compensating for the voltage drop across the load wires. Up to 0.5 volt in each load wire can be compensated for by using remote error sensing connections.

3-11 **Procedure** (Refer to Fig. 3-4)

a) Remove jumper links (3)-(4) and (6)-(7). Connect the load to either the front or rear output terminals. Keep the voltage drops in the leads to as low a value as is practical for the application by using sufficiently heavy gauge wire.

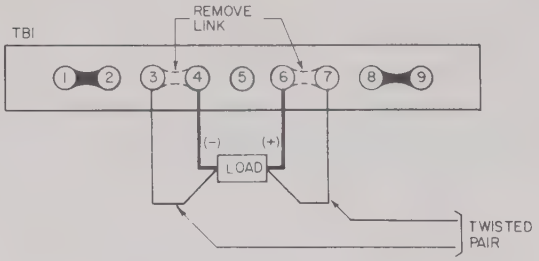


FIG. 3-4: CONNECTIONS FOR REMOTE ERROR SENSING.

b) Using a twisted wire pair separate from the load connecting leads, connect terminals (3) to the negative connection at the load, and (7) to the positive connection at the load. Although the error sensing leads only carry the 1 mA bridge current, they should be at least #20 gauge wire.

c) Check the short-circuit current; it should be set to a value that is at least 50% above the highest value of current that will be used. If adjustable current limiting is to be used it should be set *after* the load and remote error sensing connections are set-up.

d) If it is found that short-circuit current cannot be set at least 50% above the intended operating current, the internal maximum current adjustment will have to be increased. (See "Maximum Current Adjustment"), Paragraph 5-3.

NOTE: An accidental open circuit in the remote sensing circuit will sharply degrade the regulating function and cause the output ripple to rise. Protective diodes CR211 and CR212 prevent excessive overvoltage at the output terminals. If both sensing leads are opened, the rise in output voltage is negligible. If the negative sensing lead is opened, the output voltage will drop about one volt; if the positive sensing lead is opened, the output voltage rise will be approximately 1 volt. In addition, an open load circuit leaving the error sensing terminals connected to the load, may be damaging to the supply since the load current will attempt to flow through the sensing circuit. When using remote error sensing, the power supply should be OFF when load and sensing connections are being made. Connect the load before connecting the sensing wires and conversely, remove the sensing wires before the load leads.

3-12 CONSTANT CURRENT OPERATION

3-13 The ABC power supply, normally a constant voltage supply, can be readily converted to supply constant current. In the constant current operating mode, an external sensing resistor R_s and a current control R_{cc} are connected to the voltage comparison bridge externally, while the internal voltage control is disconnected. The voltage drop across R_s will now be regulated, thus providing constant current from the power supply. Characteristic of the constant current

supply is its ability to change its output voltage automatically in order to maintain a constant current through a range of possible load resistances. This output voltage which the supply delivers under constant current conditions is referred to as *"Compliance Voltage"*.

3-14 The current sensing resistor R_s is chosen to develop a one volt drop at the maximum desired current. It is calculated by dividing this current into one volt. The value of R_s is not critical and can be the nearest standard resistance value available. Several facts should be kept in mind, however, when choosing R_s. A compromise must be made between a large and a small value. While a large value is desirable for good current regulation, it also leads to a larger voltage drop and its consequent greater temperature rise. It must be remembered that all the load current is flowing through R_s and the input to the regulator is connected to it. It is, therefore, vital that all extraneous changes across R_s, i.e., resistance change due to temperature, are kept to a minimum. A high quality, low T.C. (20 PPM) resistor, at least ten times the actual wattage needed, is therefore strongly recommended.

3-15 The current control resistor, R_{cc}, is chosen on the basis of the control ratio of the Kepco Comparison Bridge, and V_s the maximum voltage across R_s. If R_s was selected for 1 volt drop, then V_s = 1 volt and $R_{cc} = V_s \times$ (control ratio), or

$$R_{cc} = 1 \text{ volt} \times \frac{1000 \text{ ohm}}{1 \text{ volt}} = 1000 \text{ ohms.}$$

A high quality, low T.C. (20 PPM) resistor is recommended for R_{cc}.

3-16 Procedure (Fixed Output Current)

(Refer to Fig. 3-5)

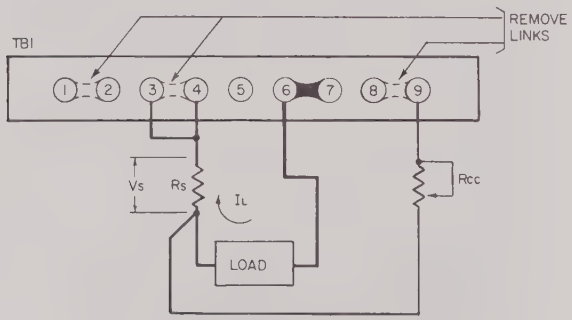


FIG. 3-5: CONNECTIONS FOR CONSTANT CURRENT OPERATION.

The set-up procedure for constant current operation is perhaps best shown by an example. An ABC 40-0.5 is to deliver a constant 500 mA into a load:

a) Select R_s. Since we want a 1 volt drop across it and I_L = 500 mA, R_s = 1 volt/0.5 A = 2.0 ohm. A resistor 2 ohm, 20 PPM, W.W. 5W, will be satisfactory.

b) The control resistor R_{cc} is found by:
$R_{cc} = V_s$ times control ratio
R_{cc} = 1 volt × 1000 ohm/volt = 1000 ohm.

c) The compliance voltage will vary from zero to 40 volts as the load varies from 80 ohms to zero ohms.

3-17 Procedure (Variable Output Current)

3-18 The load current I_L may be varied by adjusting the value of R_{cc}. The range of variable load current is from approximately 1 mA to the maximum rated output current of the power supply. This range however is difficult to achieve continuously because of the limitations imposed upon R_s. If the sample voltage (V_s) at the low end of the output current range becomes too small, degradation of regulation and stability must be expected. If the sample voltage across R_s becomes too large at the high end of the output current range, power dissipation becomes very large and compliance voltage is lost. It is therefore best to make a compromise in the selection of R_s and restrict the variable current range to approximately a 10:1 ratio. If this ratio is not sufficient, a new value of R_s should be calculated.

3-19 The following is a sample calculation for an ABC 40-0.5. A variable current is desired over the range of 100 to 500 mA. (1:5 ratio.)

a) We select R_s to drop 1 volt at the maximum current (500 mA).

$$R_s = \frac{1 \text{ volt}}{0.5 \text{ A}} = 2.0 \text{ ohm.}$$

A wire wound resistor, 2 ohm - 5 w, with a T.C. of 20 PPM or better, will be sufficient.

b) The variable control resistor R_{cc} is calculated by finding its limits:

$R_{cc\,(max.)} = V_{s\,(max.)} \times$ (Control Ratio)
$R_{cc\,(max.)}$ = 1 volt × (1000 ohms/volt)
$R_{cc\,(max.)}$ = 1000 ohm

$R_{cc\,(min.)} = V_{s\,(min.)} \times$ (Control Ratio)

Where $V_{s\,(min.)} = R_s \times (I_{L\,(min.)})$;
$V_{s\,(min.)}$ = 2 ohm × (0.1A)
= 0.2 volts

Therefore $R_{cc\,(min.)}$ = 0.2 volts (1000 ohms/volt)
= 200 ohms.

Consequently if R_{cc} is divided into two parts, a fixed 200 ohm and a variable 800 ohm, the current range from 100 to 500 mA, can be continuously controlled.

3-20 VOLTAGE PROGRAMMING

3-21 The output voltage of the ABC power supply can be varied by means of another, external voltage source. This external, variable programming source takes the place of and functions as the internal reference voltage of the ABC supply. The output voltage "follows" the variable programming source and remains in a constant proportion to it. The relationship governing this type of programming is derived from equation (1) and can be expressed as:

$$E_o = E_i \frac{R_{vc}}{R_i},$$

Where: E_o = Output Voltage to be Programmed
E_i = Programming Voltage
R_{vc} = Voltage Control Resistance (internal or external as desired)
R_i = External Coupling Resistor.

3-22 The values of the above quantities can be chosen to suit the particular application, although a few

basic facts must be considered concerning their selection. E_o is, of course, limited by the maximum capability of the supply to be programmed. E_i can be any variable DC source having parameters at least as good as the desired E_o, and being able to deliver the necessary I_b. The resistors R_{vc} are selected by first determining I_b, the desired bridge current.

Since I_b is supplied by E_i and also subtracts from the load current of the supply to be programmed, it should be kept as low as possible, but not under 100 μA.

3-23 If I_b is selected and E_i as well as the desired output voltage E_o are known, R_{vc} and R_i are calculated by these simple relations:

$$R_{vc} = \frac{E_o}{I_b} \quad \text{(Eq. 2)}$$

where $I_b = \frac{E_i}{R_i}$ (Eq. 4) and $E_o = \frac{E_i}{R_i}(R_{vc})$

Stability, more than accuracy is the dominant criteria for selecting R_{vc} and R_i, since part of the resistance can be made adjustable to compensate for tolerances and offset voltages. Another important consideration in selecting control and programming resistors is to leave a wide safety margin when determining their wattage rating and to use only low temperature coefficient units.

3-24 **Procedure** (Refer to Fig. 3-6)

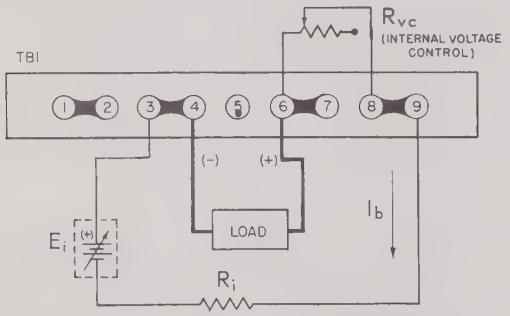


FIG. 3-6: CONNECTIONS FOR VOLTAGE PROGRAMMING.

a) Connect components as indicated in Fig. 3-6. Turn R210 ("Voltage Control Calibrate", see Fig. 2-2 for location) fully counterclockwise. THIS CONTROL IS DESIGNED TO "OPEN CIRCUIT" AT THE FULLY CCW POSITION SPECIFICALLY FOR THIS PURPOSE AND MUST BE RESET BEFORE RETURNING TO NORMAL OPERATION.

b) Component selection can best be shown in form of an example: A Model ABC 30-0.3 is to be voltage programmed over its full output range. The programming source available is variable from 0 to 6 volts, unipolar and able to deliver 1 mA of stable current. This will allow us to retain the original bridge current I_b = 1 mA and our internal voltage control R_{vc} = 30 KΩ.

c) Select R_i. Since we want an output voltage swing of 0 to 30V as the programming source varies from 0 to 6V, the desired "gain" is:

$$\frac{R_{vc}}{R_i} = 5.$$

Substituting the known values into our programming equation

$$E_o = E_i \frac{R_{vc}}{R_i}$$

and transposing for R_i we get:

$$R_i = \frac{6\text{ V } (30\text{ K})}{30\text{ V}} = 6\text{ K}\Omega.$$

Since 1 mA of bridge current flows through R_i its power dissipation is: $P_{diss} = I^2R = (1 \times 10^{-3})^2$ times $(6 \times 10^3) = 6 \times 10^{-3}$ watts. A 6 KΩ W.W. ½ W resistor will be adequate for the purpose.

d) Turn on both, the power supply and the programming source. With the programming source at 6 volts, adjust the output voltage of the power supply to 30 volts by means of the front panel control. The output voltage of the ABC power supply will now track the programming voltage with the established ratio.

3-25 SERIES OPERATION OF ABC POWER SUPPLIES

3-26 KEPCO ABC Power Supplies can be series-connected for increased output voltage, provided, the specified limits on voltage to chassis are not exceeded. Series connected supplies must be protected by means of semi-conductor diodes across the output terminals of each supply, as shown in Fig. 3-7. The peak inverse rating of these diodes must be at least as high as the output voltage of the supply to which they are connected. The continuous current rating of the diodes must be at least as large as the largest short-circuit current of the supply to which they are connected.

3-27 **Procedure** (Refer to Fig. 3-7)

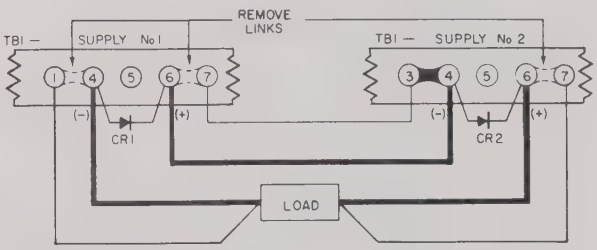


FIG. 3-7: CONNECTIONS FOR TWO ABC POWER SUPPLIES IN SERIES.

a) Connect supplies and load as shown in Fig. 3-7. Keep voltage drop in load wires as low as possible by using proper gauge wire.

b) Connect protective diodes across the respective output terminals of the supplies.

c) Remove jumpers as shown and connect error sensing leads to load. These leads carry only small currents and can be approximately #20 gauge wire.

d) Turn supplies "on" and adjust output on either one or both voltage controls as required.

3-28 PARALLEL OPERATION OF ABC POWER SUPPLIES

3-29 Two identical ABC power supplies may be operated in parallel for increased load-current output. Each supply is set approximately to the desired output voltage with its respective "Short Circuit Current"

adjustment (on the front panel) set to the maximum clockwise position. After paralleling the two power supplies, one of them (supply #1) will be at a slightly higher output voltage than the other (supply #2). Consequently, supply #1 will deliver all the load current up to the setting of its "Short Circuit Current" Adjustment. As the load is increased beyond this limit of supply #1, supply #2 takes over and delivers the additional current. The "Short Circuit Current" Adjustment of Supply #1 can now be decreased, so that approximately equal current sharing is obtained. Fig. 3-8 shows in form of a diagram, how the two supplies operate in parallel, with their respective "Short Circuit Current" Adjustments in maximum clockwise position. It will be obvious from the diagram, that the areas of load regulation are within the output current bands of the individual supply only. Therefore, load regulation should not be measured from zero to twice the load current for example, but only within the individual load current bands. Error Sensing as described in Par. 3-9 (from supply #2), may be used if precise regulation at the load is required.

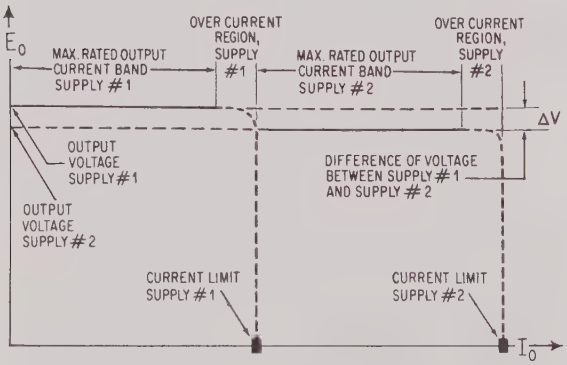

E_0
OVER CURRENT REGION, SUPPLY #1
OVER CURRENT REGION, SUPPLY #2
MAX. RATED OUTPUT CURRENT BAND SUPPLY #1
MAX. RATED OUTPUT CURRENT BAND SUPPLY #2
ΔV
OUTPUT VOLTAGE SUPPLY #1
OUTPUT VOLTAGE SUPPLY #2
DIFFERENCE OF VOLTAGE BETWEEN SUPPLY #1 AND SUPPLY #2
CURRENT LIMIT SUPPLY #1
CURRENT LIMIT SUPPLY #2
I_0

FIG. 3-8: LOAD SHARING. ABC POWER SUPPLIES.

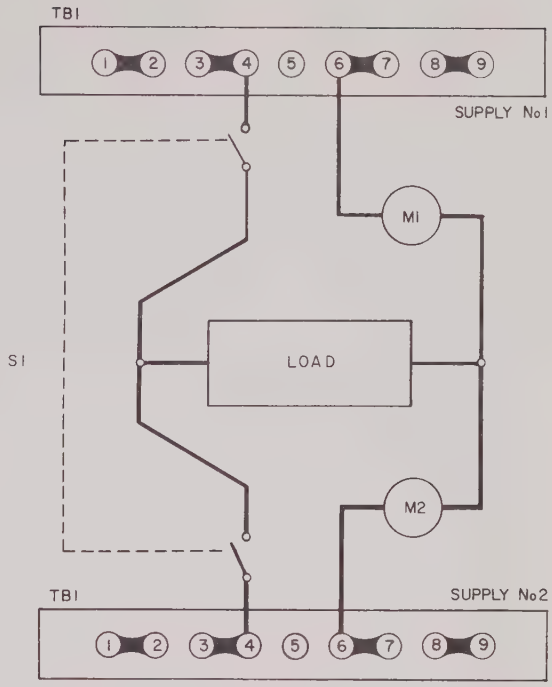


FIG. 3-9: PARALLEL CONNECTION OF ABC POWER SUPPLIES.

3-30 Procedure (Refer to Fig. 3-9)

a) Connect units as shown in Fig. 3-9. Open S-1 and connect to line.

b) Adjust both units to the approximate output voltage desired.

c) Close S-1. Observe load current meters M-1 and M-2. Adjust the front panel "Short Circuit Current" Adjustment on the unit showing the higher current on its load current meter. Turn control counterclockwise until currents on M-1 and M-2 are approximately equal.

NOTE: When paralleling power supplies, care should be exercised to avoid turning the voltage control of any individual supply close to zero. This precaution is necessary because the current flowing in the voltage control is no longer the regulated value of I_b, but instead approaches a value close to E_o/R_{vc} and may thus become excessive as R_{vc} is reduced in value.

SECTION 4 THEORY OF OPERATION

4-1 GENERAL

4-2 The ABC All-Transistor Power Supply consists of several major sections. First, the main power source with pass element and driver; second, the error signal amplifier; third, the comparison bridge, and finally, the auxiliary supplies.

4-3 CIRCUIT DESCRIPTION

(Refer to Fig. 4-1 and Fig. 4-3)

a) *The main DC power* is derived from a center-tapped winding on T1, and connected to a conventional full wave rectifier with capacitor input (CR204, CR205, C204). The main power supply delivers the operating voltage for the pass element and supplies the output current.

b) *The pass element or series control element* (Q1) is connected in series with the negative output terminal so that the unregulated voltage from the rectifier circuit is divided between it and the load. By changing the equivalent resistance of the series control element, the voltage drop across it is made to change in such a way as to maintain a constant output voltage. The base drive current for the pass element is supplied by Q204, which in turn is driven by the control signal from the error-signal amplifier.

c) *The Error Signal Amplifier.* This DC coupled, voltage amplifier consists of Q201, Q202, and Q203. It has the function of amplifying the signal derived from the comparison bridge to a level suitable to drive Q204. In addition, Q201 is utilized as a current limiting stage. Its operating point is set by R203 and R3 in such a way that any increase in output current will tend to saturate transistor Q201, and thereby reduce the drive signal to Q204.

d) *The Comparison Bridge.* This four-arm electrical bridge circuit is the regulating and controlling element in most Kepco Power Supplies. In the ABC All-Transistor Model, it consists of CR209 (E_r), R210, R211 (R_r), and R4 (R_{vc}). The fourth arm is constituted by the output voltage (E_o). As shown in Fig. 4-1, the reference voltage (E_r) in series with R_r is compared continuously to the output voltage (E_o), in series with the voltage control resistor (R_{vc}). At balance, a constant current is flowing through the bridge, keeping the error-signal voltage at the bridge terminals A and A' at approximately zero volts. Any deviation from the set output voltage at balance will tend to change the bridge current in the sensing half and thereby produce an error-signal at the bridge terminals A and A'. This error-signal is then amplified and acts as a control signal for the series regulator element, changing the voltage drop across it in such a way as to compensate for the change in output voltage.

e) *Auxiliary Supplies:* (Refer to Fig. 4-3)

1) Amplifier Power Supply. – This full-wave, capacitor-filtered DC source consists of a center-tapped winding from T1, silicon rectifiers CR201 and CR202 filter capacitor C201 and dropping resistor R1. It provides the operating voltage for the amplifier and the comparison bridge circuit.

2) Driver Collector Supply. – A half wave, capacitor-filtered supply is derived from a winding on T1, rectified by CR207 and filtered by R213 and C203. It delivers collector voltage to driver transistor Q204.

3) I_{co} Supply. – This full-wave, capacitor-filtered supply is derived from the same winding on T1 which supplies the main DC power. CR205 and CR206 are the rectifiers and C205 serves as filter-capacitor. This supply has the function of providing the turn-off bias for the series pass element, especially at higher temperatures.

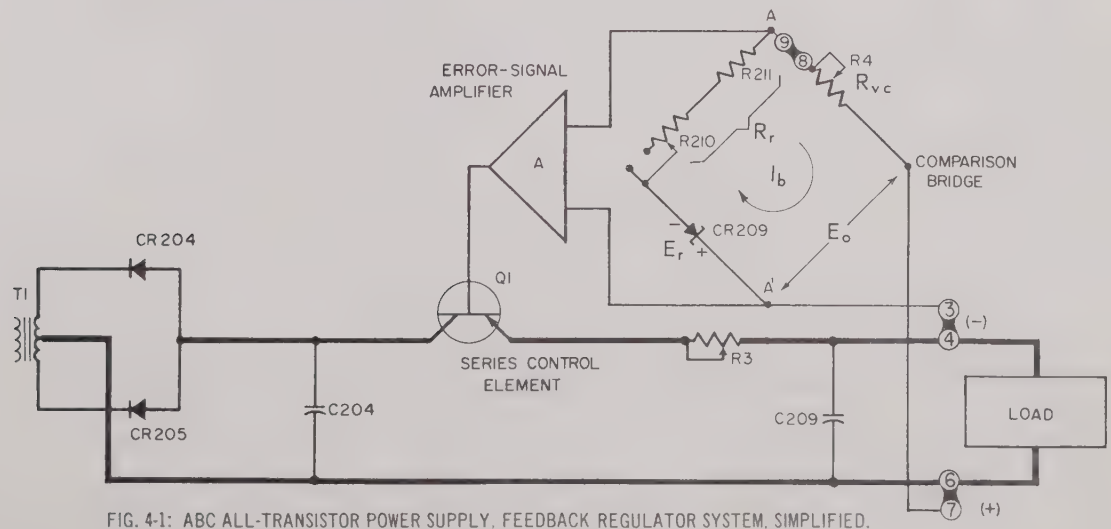


FIG. 4-1: ABC ALL-TRANSISTOR POWER SUPPLY, FEEDBACK REGULATOR SYSTEM, SIMPLIFIED.

SIMPLIFIED DIAGRAM & CONNECTION GUIDE FOR
ABC ALL-TRANSISTOR MODELS

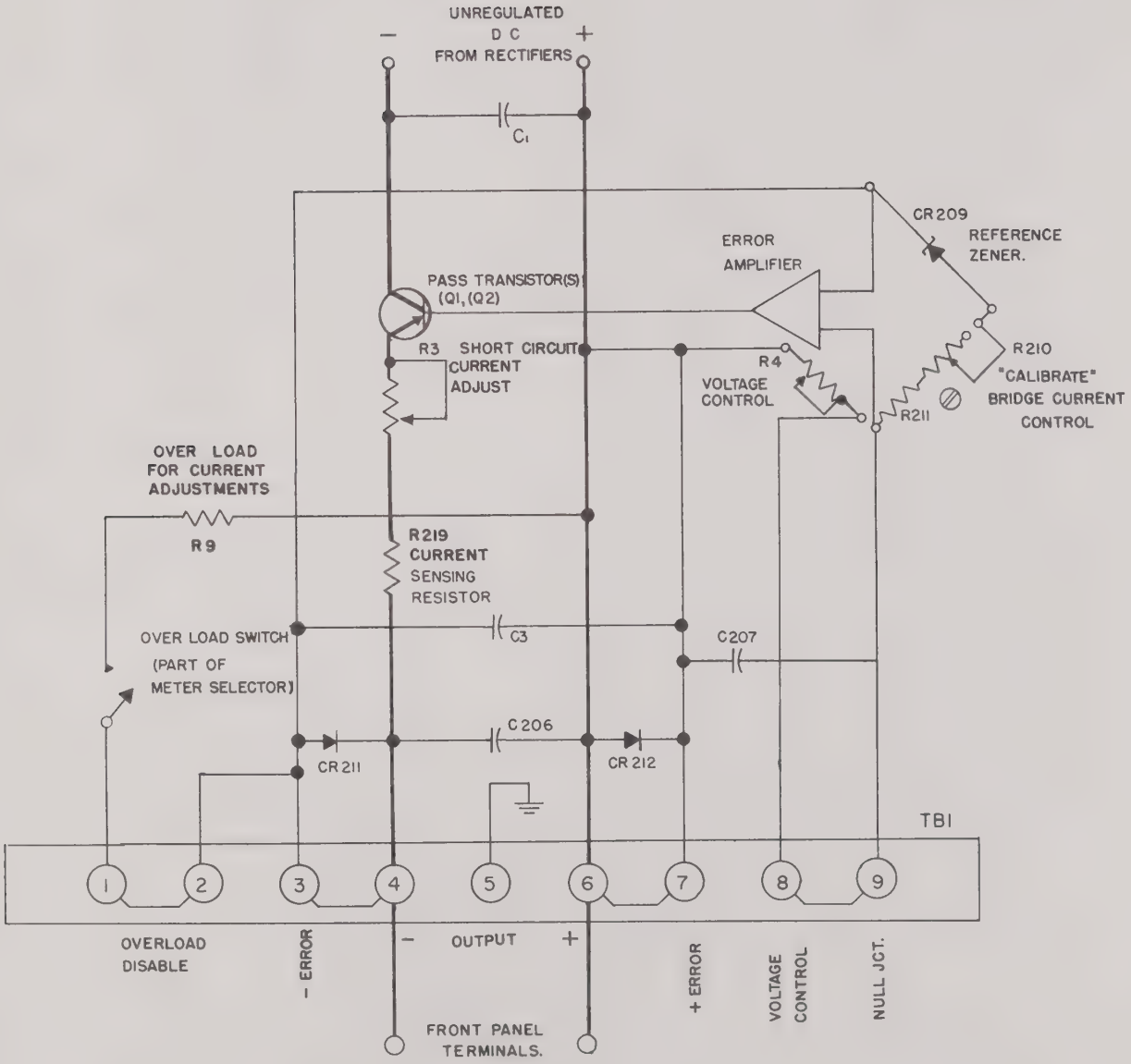
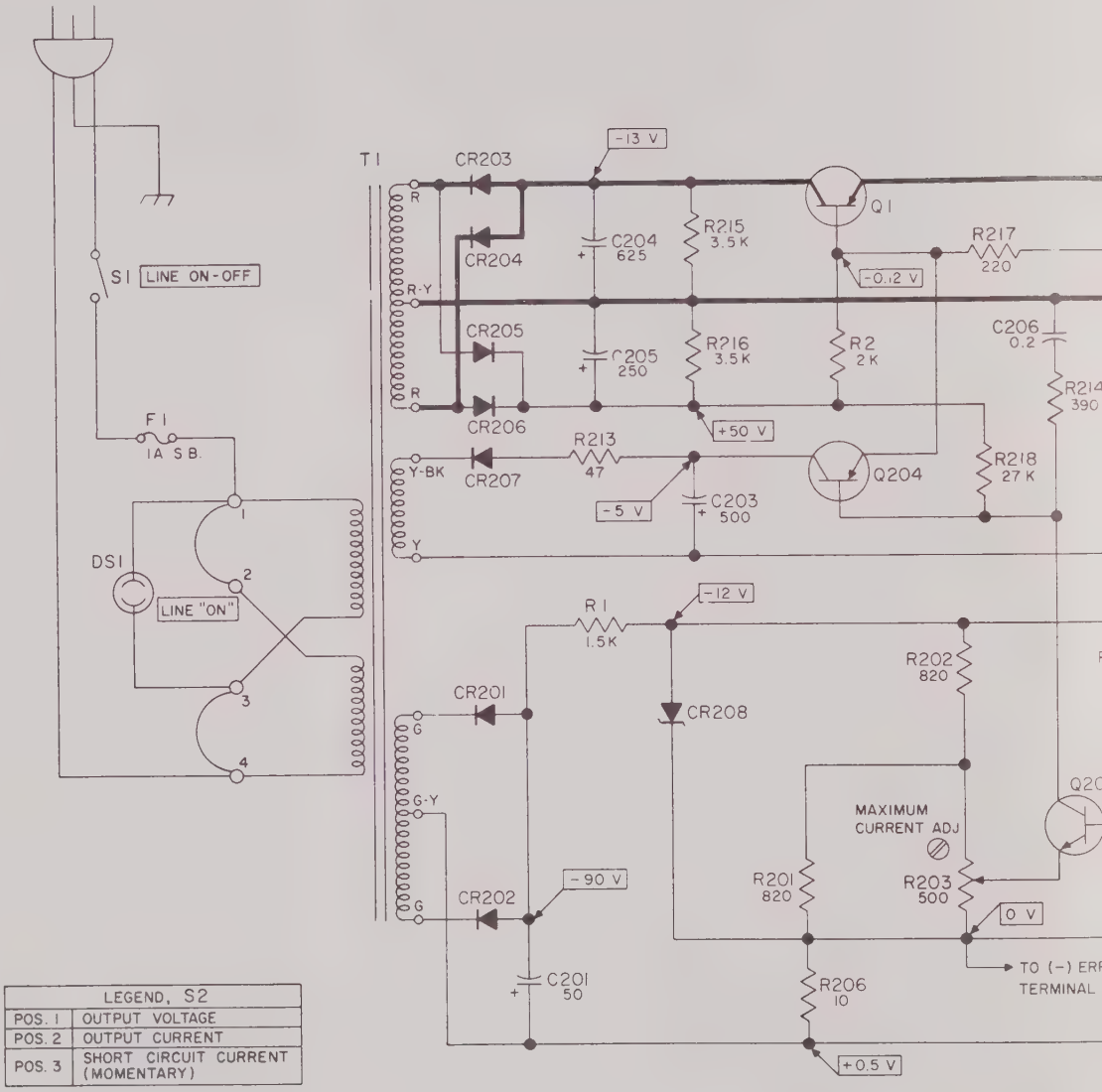


FIG. 4-2: ABC ALL-TRANSISTOR POWER SUPPLY CONNECTING GUIDE.

DM06255 6-26-67



LEGEND, S2	
POS. 1	OUTPUT VOLTAGE
POS. 2	OUTPUT CURRENT
POS. 3	SHORT CIRCUIT CURRENT (MOMENTARY)

NOTES

1. ALL RESISTOR VALUES ARE IN OHMS, K = 1000
   ALL CAPACITOR VALUES GIVEN IN MICROFARADS, K = 1000
2. S2, M1, R7, R6; ON METERED MODELS ONLY.
3. ITEMS WITH REFERENCE DESIGNATION 200 - 299 ARE MOUNTED ON PRINTED CIRCUIT BOARD
4. VOLTAGES ARE DC, TYPICAL VALUE, MEASURED TO (-) DC OUTPUT TERMINAL WITH 20 K/V METER; AC LINE 115 V; OUTPUT SET TO MAXIMUM VDC, NO LOAD.
5. TRANSFORMER CONNECTIONS SHOWN FOR 115 V AC OPERATION.

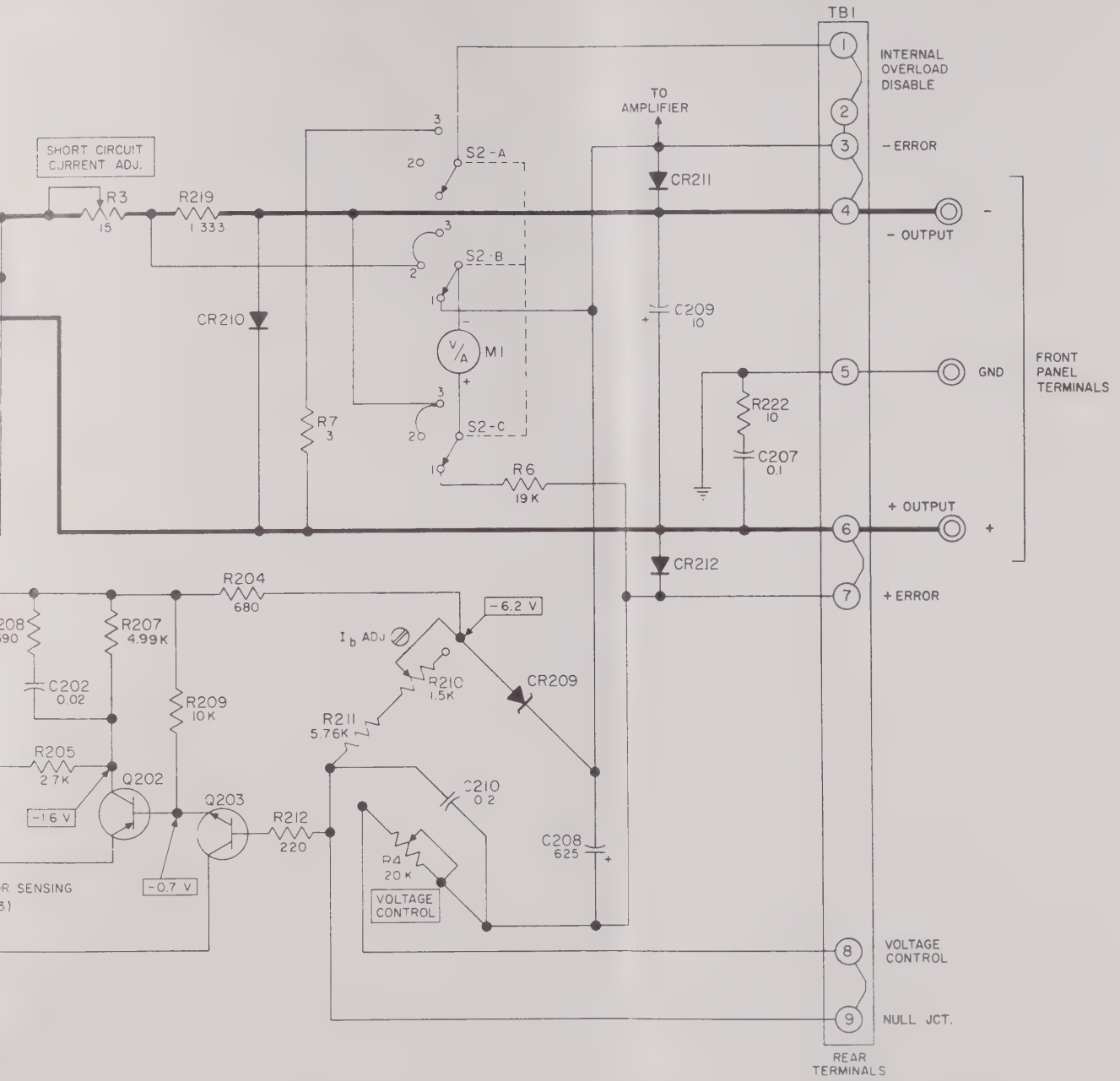


FIG 4-2 MAIN SCHEMATIC, MODEL ABC 18-0.5(M)

kepco
Data subject to change without notice
PATENT NOTICE: Applicable Patent Nos will be supplied on request

SECTION 5 MAINTENANCE

5-1 GENERAL

5-2 Conservative rating of all components, and avoidance of congested layout in the ABC supplies keeps maintenance problems to a minimum. If component failure does take place however, easily accessible components in conjunction with the information contained in this manual, will enable the user to keep the down time to a minimum.

5-3 INTERNAL ADJUSTMENTS

(Refer to Fig. 2-1 and Fig. 2-2)

a) **Voltage Control Calibration.** The voltage calibrating resistor R210 adjusts the bridge current (I_b) in the comparison bridge. For the procedure of this adjustment refer to Paragraph 3-4. For noncritical applications, the front-panel "Voltage Adjust" control may be calibrated by setting it to its maximum clockwise position and adjust R210 to the maximum rated output voltage of the supply.

b) **Maximum Current Adjustment.** The maximum current adjust control (R203) sets the maximum current that can be controlled by the front panel "Short Circuit Current Adjust". When the front panel control is set to its maximum clockwise position, R203 is adjusted in such a way as to start limiting action when the output current exceeds the maximum rated value for the supply. This adjustment is set at the factory and should not require resetting except following the replacement of a transistor or zener diode, or when remote error sensing is used with voltage drops approaching 0.5 volt in the negative load connecting lead.

5-4 TROUBLESHOOTING

5-5 Servicing beyond simple part replacements should be attempted only by personnel thoroughly familiar with solid state component techniques and with experience in closed loop circuitry. Troubleshooting charts showing resistance and voltage readings are of limited usefulness with feedback amplifiers. We have therefore not included them here. Presented instead, is a circuit description, parts location diagrams, a simplified schematic of the feedback circuit and the main schematic with the more important voltage readings. It has been our experience that with these aids, a skilled technician will in most cases be able to service the supply. In more difficult cases, the nearest Kepco Field Engineering Office, or the Kepco Repair Department at the factory, is always available for prompt service.

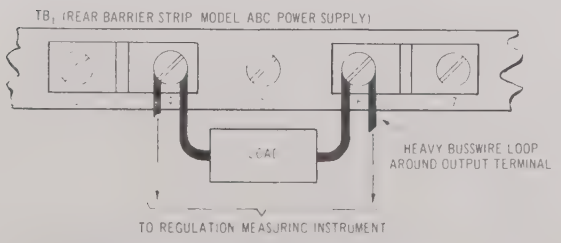

TB1 (REAR BARRIER STRIP MODEL ABC POWER SUPPLY)
LOAD
HEAVY BUSSWIRE LOOP AROUND OUTPUT TERMINAL
TO REGULATION MEASURING INSTRUMENT

FIG. 5-1: APPROXIMATION OF A 4-TERMINAL NETWORK.

5-6 POWER SUPPLY MEASUREMENTS

(Refer to Fig. 5-1 and Fig. 5-2)

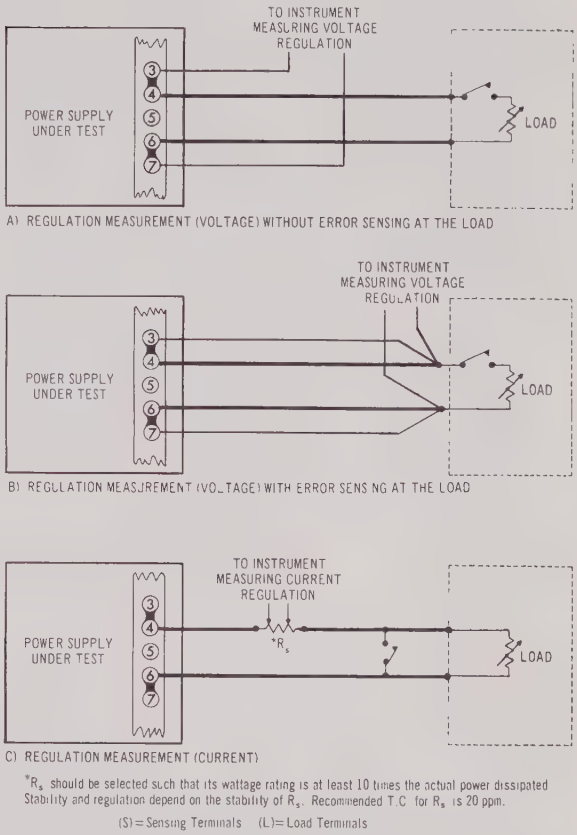

TO INSTRUMENT MEASURING VOLTAGE REGULATION
POWER SUPPLY UNDER TEST
3
4
5
6
7
LOAD
A) REGULATION MEASUREMENT (VOLTAGE) WITHOUT ERROR SENSING AT THE LOAD
TO INSTRUMENT MEASURING VOLTAGE REGULATION
POWER SUPPLY UNDER TEST
LOAD
B) REGULATION MEASUREMENT (VOLTAGE) WITH ERROR SENSING AT THE LOAD
TO INSTRUMENT MEASURING CURRENT REGULATION
*Rs
POWER SUPPLY UNDER TEST
LOAD
C) REGULATION MEASUREMENT (CURRENT)
*Rs should be selected such that its wattage rating is at least 10 times the actual power dissipated
Stability and regulation depend on the stability of Rs. Recommended T.C for Rs is 20 ppm.
(S) = Sensing Terminals (L) = Load Terminals

FIG. 5-2: CONNECTIONS FOR TAKING REGULATION MEASUREMENTS.

5-7 Measurement of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance, or after component replacement. Since these measurements require special techniques to insure correct results, suggestions for their performance are given below:

a) **Required Instrumentation:**

1) Constant A.C. Supply voltage with provisions for "stepping" or varying the voltage over the specified range (105-125V); a variable autotransformer is generally adequate. It must be rated to deliver the input current of the unit under test.

2) Resistive load, variable, with on and off switch and capable of dissipating the full output power of the unit under test.

3) D.C. Voltage Monitor, Differential Voltmeter, or Power Supply Analyzer which displays the percentage regulation directly.

4) Current sensing resistor, for current regulation measurements, four terminal device.

5) AC ripple monitor, sensitivity better than 1 mV Ballantine Model 302C, or H.P. Model 400H.

6) Optional: Oscilloscope, vertical sensitivity better than 1 mV/cm.

b) *The Four Terminal Network* is an essential device for precise measurement of regulation. It can be approximated by the method shown in Fig. 5-1. Fig. 5-2 above shows the proper location of instrument leads when measuring regulation. The principle governing this method of measurement is simply *not* to measure any voltage drops due to load current flow. This can only be avoided by measuring regulation either directly at the sensing leads or by the use of the four-terminal network. If the load must be connected to the front terminals, remote error sensing must be used for optimum regulation at the load. (Refer to Par. 3-9.)

c) *Voltage Regulation* is defined as the amount of output voltage change resulting from a specified change of line voltage or from a change in load resistance. It can be expressed as an absolute change ΔE_o or as a percentage in reference to the total output voltage E_o:

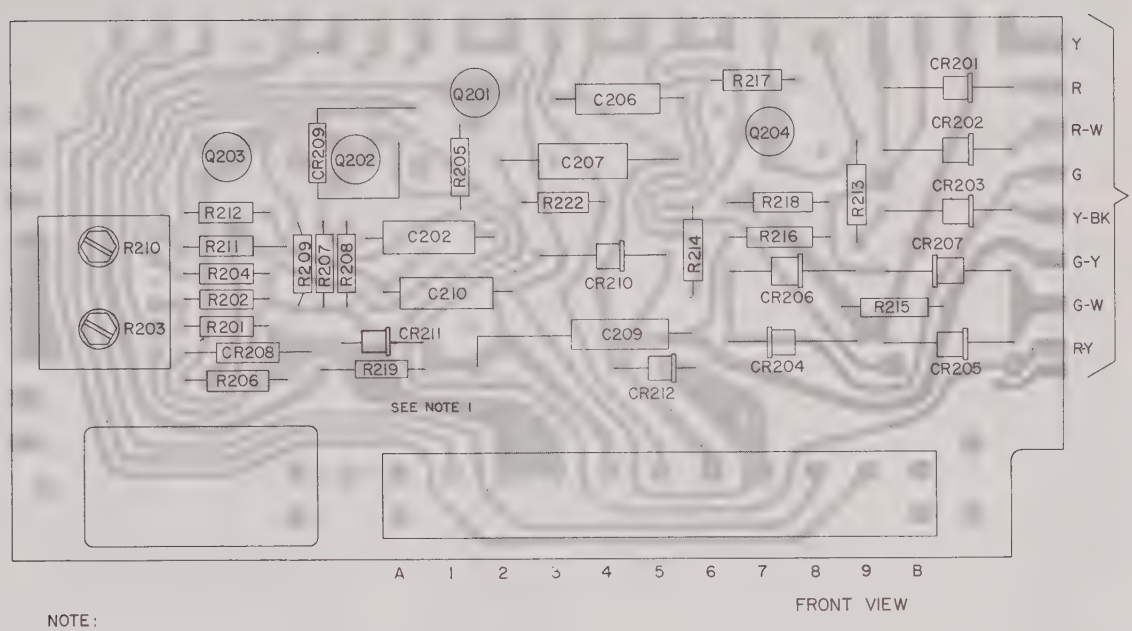
$$\% \text{ Voltage Regulation} = \frac{\Delta E_o}{E_o} (100\%)$$

d) *Current Regulation* is defined as the amount of output current change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change ΔI_o, or as a percentage in reference to the total output current I_o:

$$\% \text{ Current Regulation} = \frac{\Delta I_o}{I_o} (100\%)$$

e) *Ripple.* An oscilloscope of suitable sensitivity or a true rms indicating meter may be used to measure the ripple at the output of the power supply. Suitable DC blocking must be provided. A 0.1 μF capacitor of sufficient working-voltage is generally adequate. The peak-to-peak to rms ratio for a pure sine wave is approximately equal to 2.83:1. For a broken waveform such as from a series regulator, 3:1 is a good approximation. Ripple measurements across current sensing resistors must be converted to current by the use of Ohm's law.

NOTE: Great care is required if valid measurements of current ripples are desired. The use of completely shielded sensing resistors and load cables may be necessary to get accurate readings.



NOTE:
1. R219 WILL BE LOCATED ON S2 ON METERED UNITS

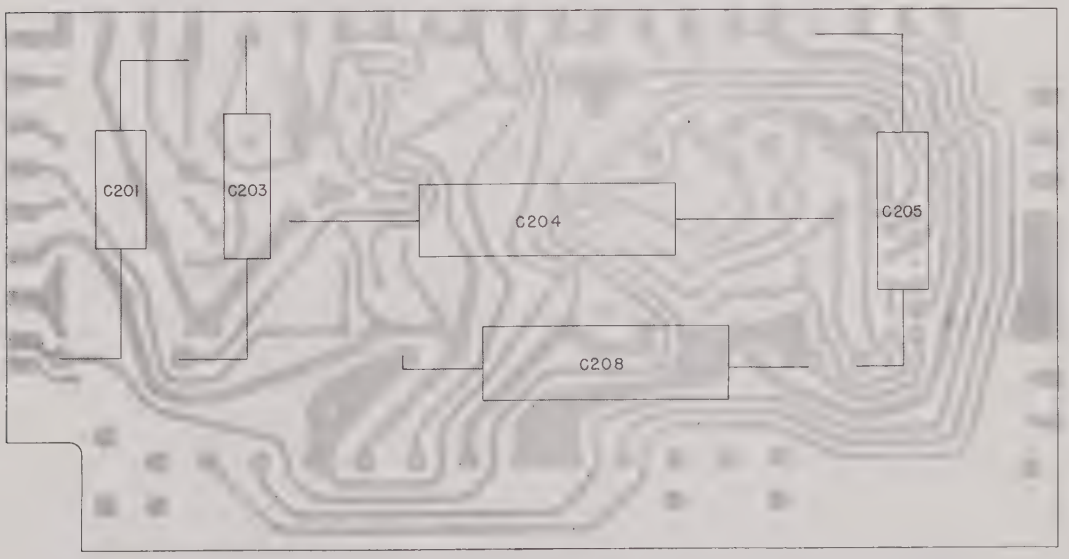
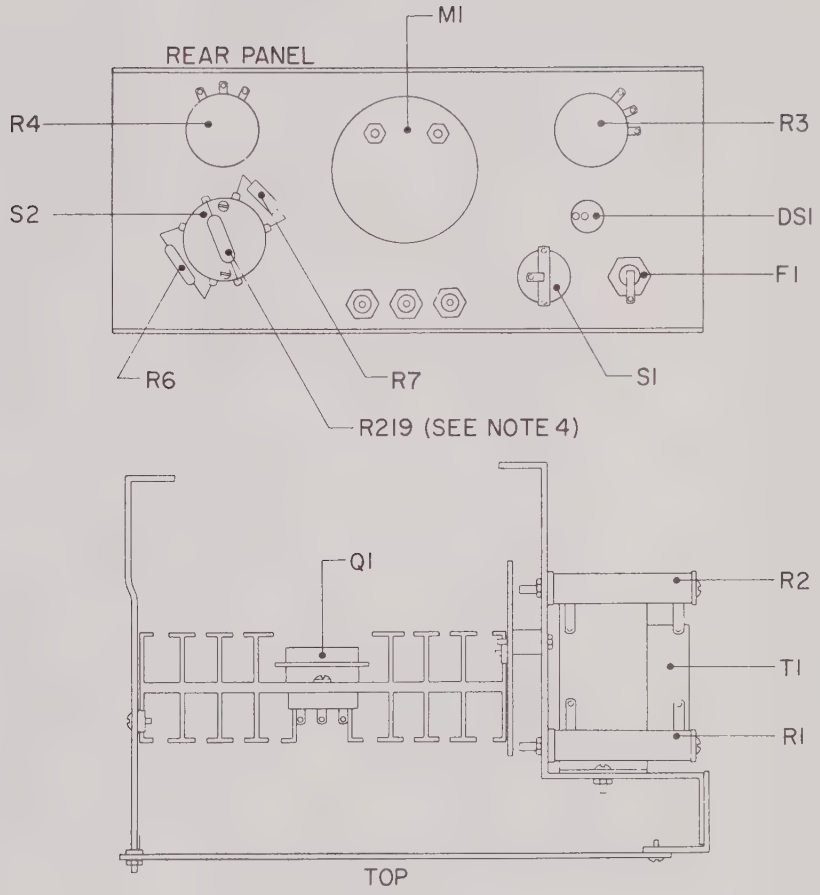


FIG. 5-3 COMPONENT LOCATION, PCB-1



NOTES:

1. M1 AND S2 ARE DELETED ON UNMETERED UNITS
2. THIS DRAWING USED ON UNITS ABC30-03M, ABC18-0.5M, ABC10-0.75, ABC2-1M
3. ON UNIT ABC2-1M RESISTOR R7 ON SWITCH S2 IS DELETED
4. R219 LOCATED ON PCB-1 ON UNMETERED UNITS

FIG. 5-4 COMPONENT LOCATION, MAIN CHASSIS

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MAIN CHASSIS, MODEL ABC 18-0.5 (M) Code 6-1764

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
DS1	1	Pilot Light, Assembly	Industrial Devices 1050A17	152-0069
F1	1	Fuse, Slo Blo 1 a, 250 v	Bussman MDL-1	141-0047
*M1	1	Meter 0-20v, 0-750 ma, 2 1/2"	General Electric DW91	135-0284
Q1	1	Transistor, PNP	Delco 2N174	119-0016
R1	1	Resistor, Power, Tubular 1.5 K ohm, 10 w, 5%	Ohmite Mfg. D-48-F-1500	115-0494
R2	1	Resistor, Power, Tubular 2.0 K ohm, 10 w, 5%	Ward Leonard 10F2000	115-0148
R3	1	Resistor, Power, Rheostat 15 ohm, 12.5 w, 10%	Hardwick Hindle 0110	116-0782
R4	1	Resistor, Variable, W.W. 20 K ohm, 10-Turn, 3%	IRC 8000 Series	115-1224
*R6	1	Resistor, Fixed, Precision 19 K ohm, 1/2 w, 1%	Kidco C-1/2C	115-1123
*R7	1	Resistor, Fixed, Power, Axial 3 ohm, 3 w, 5%	Ward Leonard 3X3	115-0580
S1	1	Switch, Toggle. SPST 3 a, 125 v, AC	Carling AA232-71	127-0152
*S2	1	Switch, Rotary 3 Pole, 3 Position	C.T.S. SR212-10634-1	127-0167
T1	1	Transformer	Kepco Magnetics	100-1366

*Metered Models Only

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

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PRINTED CIRCUIT BOARD, MODEL ABC 18-0.5 (M) Code 2-2565

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C201	1	Capacitor, Electrolytic, Pigtail 50 µf, 150 v, 10%	Industrial Cond. 10B936	117-0127
C202	1	Capacitor, Fixed, Mylar 0.02 µf, 200 v, 10%	TRW Type X663F	117-0377
C203	1	Capacitor, Electrolytic, Pigtail 500 µf, 6 v, 10%	Industrial Cond. 1B1355RM	117-0117
C204, 208	2	Capacitor, Electrolytic, Pigtail 625 µf, 40 v, 20%	General Electric 43F7244AA1	117-0405
C205	1	Capacitor, Electrolytic, Pigtail 250 µf, 50 v, 10%	Industrial Cond. 1B1146	117-0150
C206, 210	2	Capacitor, Mylar 0.2 µf, 200 v, 10%	TRW Type X663F	117-0236
C207	1	Capacitor, Mylar 0.1 µf, 600 v, 20%	TRW Type X663F	117-0316
C209	1	Capacitor, Electrolytic, Pigtail 10 µf, 50 v, 10%	Industrial Cond. 1B1280	117-0136
CR201, 202	2	Rectifier, Silicon, Pigtail	Semicon Inc. SM-140	124-0028
CR203, 204 205, 206, 207	5	Rectifier, Silicon, Pigtail	Semicon Inc. SM-110	124-0133
CR208	1	Zener Diode	Hoffman 1N1773	121-0012
CR209	1	Zener Diode	International Rect. 1N821	121-0041
CR210	1	Rectifier, Germanium, Pigtail	General Electric 1N91	122-0007
CR211, 212	2	Rectifier, Silicon, Pigtail	Solitron 124-0178	124-0178
Q201	1	Transistor, NPN	General Electric 2N336A	119-0056
Q202, 204	2	Transistor, Silicon, PNP	Hughes 2N1131A	119-0055
Q203	1	Transistor, NPN	General Electric 2N338	119-0054
R201, 202	2	Resistor, Fixed, Molded 820 ohm, 1/2 w, 10%	Allen Bradley EB8211	115-0480
R203, 210	1	Resistor, Variable, Multiple 500/1.5 K ohm, 1/4 w, 30%	C.T.S. X152	115-1208

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REPLACEMENT PARTS LIST

PRINTED CIRCUIT BOARD, MODEL ABC 18-0.5 (M) Code 6-2667

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R204	1	Resistor, Fixed, Molded 680 ohm, 1/2 w, 5%	Allen Bradley EB6815	115-0871
R205	1	Resistor, Fixed, Molded 2.7 K ohm, 1/2 w, 10%	Allen Bradley EB2721	115-0560
R206	1	Resistor, Fixed, Molded 10 ohm, 1 w, 10%	Allen Bradley GB1001	115-0052
R207	1	Resistor, Fixed, Precision, M.F. 4.99 K ohm, 1 W, 1%	IRC CES Type	115-1926
R208, 214	2	Resistor, Fixed, Molded 390 ohm, 1/2 w, 10%	Allen Bradley EB3911	115-1145
R209	1	Resistor, Fixed, Precision, M.F. 10 K ohm, 1 W, 1%	IRC CES Type	115-1821
R211	1	Resistor, Fixed, Precision, M.F. 5.76 K ohm, 1 W, 1%	IRC CES Type	115-1893
R212, 217	2	Resistor, Fixed, Molded 220 ohm, 1/2 w, 10%	Allen Bradley EB2211	115-0371
R213	1	Resistor, Fixed, Molded 47 ohm, 1 w, 10%	Allen Bradley GB4701	115-0005
R215, 216	2	Resistor, Fixed, Power, Axial 3.5 K ohm, 3 w, 5%	Ward Leonard 3X3500	115-0569
R218	1	Resistor, Fixed, Molded 27 K ohm, 1 w, 10%	Allen Bradley GB2731	115-0008
**R219	1	Resistor, Fixed, Precision 1.333 ohm, 3 w, 1%	Kidco W3	115-1109
R222	1	Resistor, Fixed, Molded 10 ohm, 1/2 w, 10%	Allen Bradley EB1001	115-0502

**On Metered Units Resistor R219 is located on Rotary Switch (S2).

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